Applications of Plant-Based Natural Products to Synthesize Nanomaterial

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Abstract

Plants are the important means of various kinds of phytochemicals with several applications in nanotechnology. Nanotechnology refers to the building and use of materials whose components exist at the nanoscale up to 100 nm in size. These biotechnological tools have been synthesized by the use of different kinds of plants. Plants have numerous natural products like tannins, saponins, flavonoids, steroids, alkaloids, and other nutritional products that can be obtained from several plant parts like seed, barks, leaves, roots, shoots, flowers, and stems. It has been reported that the extracts from plants act as a powerful pioneer for a nanomaterial production in safe procedures. As the plant extracts have numerous secondary metabolites, it plays part as stabilizing and reducing factors for the bioreduction reaction to form new metallic nanoparticles. These plant-based nanoparticles have various applications in different fields especially in biofuel production.

Keywords

Nanoparticles · Plants · Natural · Nanomaterials · Applications · Substances

2.1 Introduction

In the present days, nanoparticles and its various items have become principal components of our items in routine, so metallic nanoparticles like silver in antiperspirants and particles with improved discharge properties into meds are known as nanoparticles and the whole distance to "nano impregnations" of spray lodges,

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baths, and cleaning bowls (Moss and Siccardi 2014; Vincent and Loeve 2014; Kettler et al. 2016). As these nanomaterials, which include particles having diameters in the range of hundred nanometers, have now significant role in our routine life, there are also concerns about a possible toxic effect of these nanomaterials on humans and environment as well (Roy et al. 2017). However, such evaluations usually disregard the truth that nature is a proficient nanotechnologist itself, with various precedents of general nanomaterials emerging from sources that are natural, like mineral springs, volcanoes but specifically from living beings also. Actually, life rotates around the cell which itself is microscopic in size and metabolize molecules which are picoscopic (Kajander et al. 2001; Ciftcioglu et al. 2006; Urbano and Urbano 2007).

Presently, we sometimes fortuitously judge the emerging field of nanomaterials. Here, we will shortly discuss the rising area of natural nanoparticles. Actually, there is a demand for a difference among natural nanomaterials, such as already found or synthesized in the environment without man involvement, and substances which are "bio" and "nano" as well. In another case, the predicate "natural" corresponds to "biological," as in "natural products," which mentions mainly biological substances (Mukherjee et al. 2001; Patel et al. 2015a, b; Pasula and Lim 2017). Through the earliest starting point, all of us ought to complement to grounds of nanoparticles (NPs) as is broad and incidental. Figure 2.1 illustrates the synthesis of nanomaterials from plants and their applications in various fields.

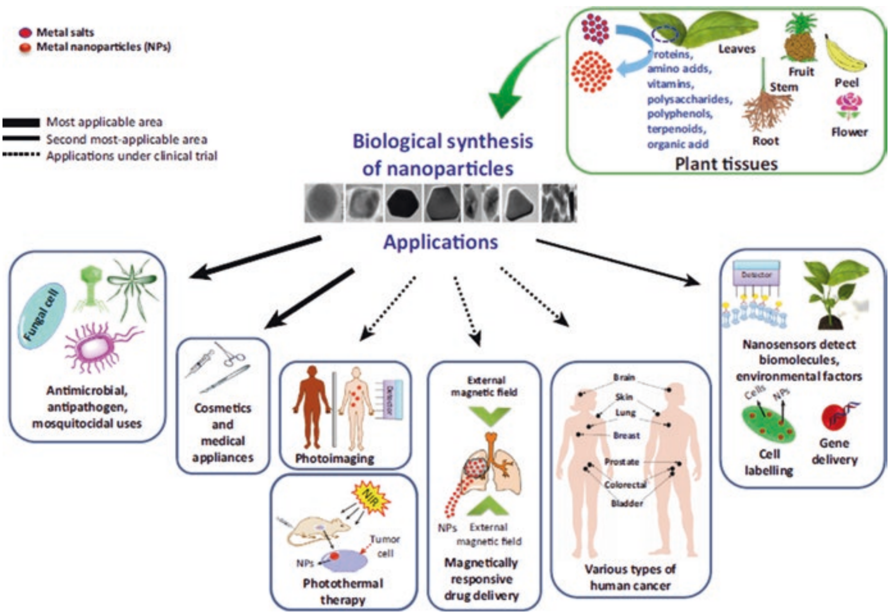


Fig. 2.1 Biological synthesis and applications of metallic nanoparticles in environmental and biomedical areas. (Modified from Singh et al. 2016a, b)

2.2 Inorganic Nanoparticles Derived from Natural Sources

In the earth, so many inorganic nanoparticles are present which are derived from natural sources. So such particles are common, so far more often than nonnatural. Volcanic powder mists contain a comprehensive assorted diversity in polydispersity miniaturized scale plus nanomaterials. Such particles extend in size somehow from 100 to 200 nm and are synthetically basically made out of composites of iron and silicates. These particles are deliberately floating in air and if only once heaved can prompt attentive pulmonary disorders. “Carbon nanotube” sediment gathered from the cremation of Texas pine, for example, in point, involves many layers (15–70 nanometers of size) of carbon nanotubes. Such carbon-based particles deliberately turned out to be airborne and present serious well-being perils to creatures and the human populace (Murrand Guerrero 2006).

Miraculously, drinking water, when seen under microscope, which could be loaded with variously sized nanoparticles just like minute strong materials of every shape. Generally, these particles are not of good quality and cannot easily be molded and are very much characterized. There are inexhaustible instances of characteristic nanomaterials structured thusly, for example, the $CaSO_4$ and silicate particles in spring water (Wu et al. 2016). In reality, these inorganic substances meanwhile urged counterparts to produce a scope of similar particles dependent on normally happening particles, for example, refined nanoparticles of Fe_3O_4 and MnO_2 (Song et al. 2010; Cho et al. 2017).

Likewise, in such “straightforward” physical occasions, there are comparable however progressively controlled molecule-inducing forms, frequently made on regular oxidation. One constantly noticed precedent of hydrogen sulfide gas oxidation (HS) condensed in volcanic eruptions or/and in wells which are common in numerous locality of our planet (Ezoe et al. 2002; Berlo et al. 2014). All things considered must be well characterized—at any rate with respect to synthetic course of action—and could get significant consideration.

2.3 Biological Synthesis of Nanomaterials

To be sure, the living cell is habitually managing “nanotechnology,” in other words with objects of a nanoscopic rate. Just to wind up an inclination for sizes, basic strand of DNA in width is almost equal to 2.5 nm (Shors 2011). Henceforth some cells that lie in microbes are specific and are included in the field of nanotechnology. Some procedures are somewhat very much perceived and contemplated with respect to some metals like selenium and sulfur just as metallic NPs (Kuppusamy et al. 2016). The particles created by such biogenic production lines are generally of decent quality, for example, little circular states of a practically uniform size. Not astoundingly, such natural procedures might be inappropriate ultimately to create materials of good quality and then to deliver.

To be sure, the subtraction of ecological contaminants (e.g., overwhelming metals, natural and inorganic toxins), from defiled destinations utilizing nanomaterials or nanoparticles shaped in or by plants, parasites, and microbes with the aid of nanotechnology, frequently referenced to as nanobioremediation (NBR), is a growing, earth-responsive, and practical substitute to customary compound strategies (Singh and Walker 2006; Yadav et al. 2017). At this point, the three fundamental methodologies of present-day bioremediation grasp the utilization of organisms, plants, and sequestered chemicals, for event, nitrate reductase, or laccase (Sanghi et al. 2011). All things being equal, there is likewise an extra plus point of that strategy. Presently, the nanoparticles made by those life forms are not all encompassing spotted as contaminants however basically as esteemed nanoparticles of a pretty much common birthplace. Inside this specific situation, a portion of these bioreductively framed "normal" nanomaterials have been found currently with focus on likely restorative and horticultural entries (Salata 2004; Li et al. 2011; Duhan et al. 2017; Iavicoli et al. 2017). It is conceivable, for example, to tenderfoot innocuous microorganisms, for example, *Staphylococcus carnosus* and *Saccharomyces cerevisiae*, to create genuinely homogeneous selenium nanoparticles from selenite, an ion with normal measurements of 60 and 80 nanometers, correspondingly (Zhang et al. 2012; Estevam et al. 2017). Such particles are assembled from the microbes and yeasts after rupture of the cell. The investigators have wandered about conceivable implementations as nourishment increments and most likely as antimicrobial operators as a portion of such particles uncover an unambiguous antimicrobial movement (Zhang et al. 2012; Estevam et al. 2017; Skalickova et al. 2017).

In the area of farming, likely implementations have considerably much surfaces and a conceivable "cap trap" of immediately enhancing dirt with selenium for braced sustenance items, of giving plants components for their characteristic obstruction frameworks, and of dispensing with plant pathogens appears to be doable (Estevam et al. 2017). Inside this unique situation, one needs to push such normally delivered particles are not proportionate to modernly created materials. They are not "artificially unadulterated" and every now and again likewise contain a "characteristic" covering of proteins whose design is an impression of the yeasts or microscopic organisms they have been made in. Later the organic action of such characteristic particles may come from the mass material of the molecule itself, for example, selenium, from different mixes kept or restricted to the molecule and furthermore from the covering, which is as often as possible wealthy in proteins (Prakash et al. 2009; Wang et al. 2010; Yazdi et al. 2012; Estevam et al. 2017). In cases like these, a broad "intracellular diagnostics" is needed to explain the correct target(s) and point-by-point method(s) of activity (Mániková et al. 2014). Eventually, one may foresee a complex procedure by which microorganisms are created or tainted and by remediating that dirt delivers unmistakable nanoparticles which might be reaped and push off in prescription, horticulture, or several more appropriate applications. The significant merits of these techniques might be impressive and are not unrealistic additionally, as germane contaminants, for example, extensive metals, regularly likewise describe the establishment of mostly intriguing particles. In any case, there might be some further advantages, particularly with regard to pathogenic organisms and microorganisms. Various examinations have built up that the arrangement of nanomaterials by or inside pathogenic microscopic organisms is a compelling instrument to cancel those living beings. It has been seen, for example, that pathogenic strains of *Staphylococcus aureus*, for example, HEMSA and HEMSA 5 M, reduce SeO_3^{2-} to basic selenium when tested with incredibly extraordinary convergences of this anion (around 2 mM) in a shallow endeavor to manage this experience (Estevam et al. 2015). At last, this defensive plan comes up short, and the stores of selenium framed inside the microscopic organisms kill these cells. This sort of "self-destructive normal nanotechnology" is found between numerous microorganisms and organisms, just as pathogenic ones. It somewhat clarifies to some degree the antimicrobial activity frequently related with reactive selenium species (RSeS), such as SeO_3^{2-}, SeO_4^{2-}, TeO_3^{2-}, and TeO_4^{2-}. These activities might be explicit for specific life forms, giving these operators and chaperon forms with specific "sensor/effector" properties. Later on, this sort of common nanotechnology thusly can give an intriguing chance to trade off, debilitate, harm, or potentially even execute such pathogenic living beings (Estevam et al. 2017).

2.4 Processing Natural Materials

Various methodologies had great impact on processing of natural materials. The subsequent particles of such regular items are of an elite nature, as they are common items, yet being twisted to an uncommon, unnatural shape and size. It is along these lines barely amazing that numerous normal items have been nanosized in the most recent few years. Cancer prevention agents, for example, rutin, have been transformed into alleged "nanocrystals" utilizing an expressive procedure which incorporates wet globule processing (WBM) and high-weight homogenization (HPH) (Müller and Keck 2008; Mauludin et al. 2009). Here, nanotechnology can be utilized to create nanoparticles with a drastically enhanced solvency, phenomenal discharge energy, and later a decent bioavailability and organic action. This technique is especially alluring in the area of—frequently sparingly dissolvable—cell reinforcements and plant items wealthy in such cancer prevention agents, i.e., materials which initially have deficient discharge energy on the lipid/fluid skin surface; however on account of the new innovation, it can nowadays be utilized effectively, for example, in beauty care products. To be sure, the guideline of nanosizing coarse materials to advance their organic movement is extremely straightforward and is for the most part dependent on the Noyes-Whitney condition, one of the real conditions in biopharmacy.

For this situation, the immersion dissolvability increments because of a higher disintegration weight, which is elucidated by a greater shape of the particles (Kelvin condition) and the diffusional separate likewise diminished (Prantl condition). Nanosizing prompts an imperative increment in the general speed of disintegration, which is particularly intriguing if dynamic constituents break up gradually or not properly soluble in water. Besides, nanosizing enhances the bioactivity of inadequately solvent dynamic fixings. Because of the expansion in dissolvability, the fixation slope, when contrasted with bigger estimated materials, is expanded (Keck and Müller 2006). Because of these more prominent structures and the simplicity of generation, nanosizing, i.e., the creation of nanocrystals, has turned into a noteworthy readiness guideline in pharmaceutics to propel the bioactivity of dynamic fixings (Müller and Keck 2012; Scholz and Keck 2015). A portion of these processed plant materials have been assessed as likely nourishment supplementation and even as characteristic medications and antimicrobial specialists (Griffin et al. 2016). NPs of normal items must be utilized in the grounds of sustenance, medication, and beautifying agents or on account of substantial scale getting together, in "green" horticulture. The exercises trial for those nanosized materials are regularly encouraging, yet there is a well parity of contentions which should be estimated. Therapeutic plant is equivalently clear and altogether simpler than withdrawal, refinement, and detailing of the dynamic component(s) kept in that. It additionally delivers no or minimal waste. Also, NPs that are basically "normal," in any event to the extent their concoction organization is unstable, that contain every one of the elements in plant will not face any broad alterations and would not be treated with natural solvents. In a perfect world, they even portray a characteristic moderate discharge assembly of biologically available and naturally dynamic fixings. On account of high-pressure homogenization (HPH), such materials are additionally sanitized as progressively current investments.

2.5 Plant-Based Synthesis of Metallic NPs and Their Applications

NPs have exceptionally fascinating applications covering many areas (Chandran et al. 2006). Biological ways of making natural elements capable of reusing are shown in Fig. 2.2.

2.5.1 Traditional Strategies of Metals

Anciently metals were considered symbol of strength, and even nowadays some metals are considered as influential like gold and silver. In the eighteenth era, gold was used for mental and spiritual purification. Egyptians utilize gold

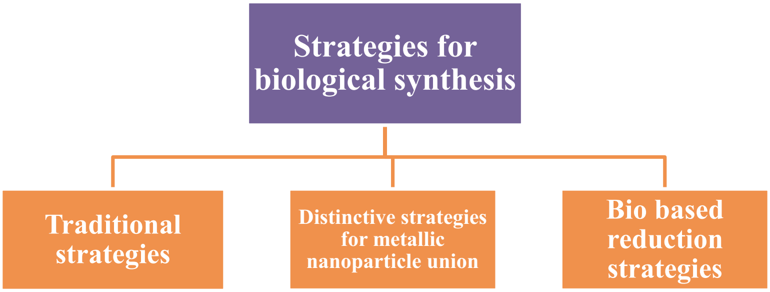


Fig. 2.2 Biological ways for synthesis of metallic nanoparticles

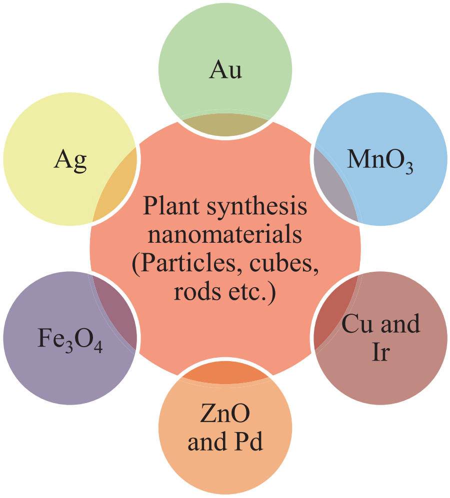


Fig. 2.3 Different plant-derived metallic nanoparticles

metal-solubilized water. The significance of gold is as yet respected in countryside areas, as the employees there prepare their rice dishes with a gold pellet to supersede the mineral lack in the body by nourishment admission. Silver is used for the healing of wounds and ulcer removal (Singh et al. 2013). Truth be told, the silver nanoparticles (AgNPs) which are colloidal in nature were utilized against antimicrobes, as wound dressing material, as tooth bond, and as a water purifier (Narayanan and Sakthivel 2011).

2.5.2 Distinctive Strategies for Union Metallic Nanoparticle

Some techniques are employed for the union of nanoparticles (nanoparticles, such as natural, compound, enzymatic, and physical). Physical strategies include ball processing, warm dissipate, beat laser desorption, atomic shaft, and flame amalgamation dispersion of NPs (Joerger et al. 2000). Synthetic techniques are utilizing radiation of high frequency and settling operators which are hurtful to human well-being. Figure 2.3 exhibits various kinds of metallic nanoparticles formed from plant means.

2.5.3 Bio-based Reduction Strategies

Silver is the biochemical feedback of silver nitrate that basically prompts the arrangement of AgNPs with the help of plant stock (Tripathy et al. 2010). The plants possess many vital biomolecules, like proteins, amino acids, and chemicals; moreover, they have some metals too. Then all these biomolecules must engage with bioreduction mechanism. So the conclusion in this metal like gold was the conversion and reduction of Au^{+} into metallic Au_0 nanoparticles in the redox catalysts (Thakkar et al. 2010).

2.6 Parts of Plants Used to Synthesize Nanomaterials

Different parts of plants are being employed in the formation of eco-friendly nanoparticles.

2.6.1 Flowers

Noruzi et al. (2011) considered an environment-friendly disposed strategy amalgamation of gold nanoparticles (GNPs) by utilizing flower petals. The concentrated media contains sufficient proteins and sugars. A portion of these utilitarian mixes are the critical wellsprings of tetrachloroaurate salt, which declines into the main part of GNPs. Additionally, flowers of *Clitoria ternatea* and *Catharanthus roseus* are utilized for the metal nanoparticle combination with required shape and sizes. The plant material-incorporated nanoparticles are viably handling disease-causing microbes, and correspondingly the therapeutic utilizable *Nyctanthes arbor-tristis* flowers for GNPs extracts are obtained through green science technique (Das et al. 2011). Fluid concentrate of flowers of *Mirabilis jalapa* goes about as a reducing agent and delivered GNPs with eco-friendly technique (Vankar and Bajpai 2010). Table 2.1 delineates the plant metabolites which speak to in the bioreduction response to union of metal NPs and their applications in pharmacology.

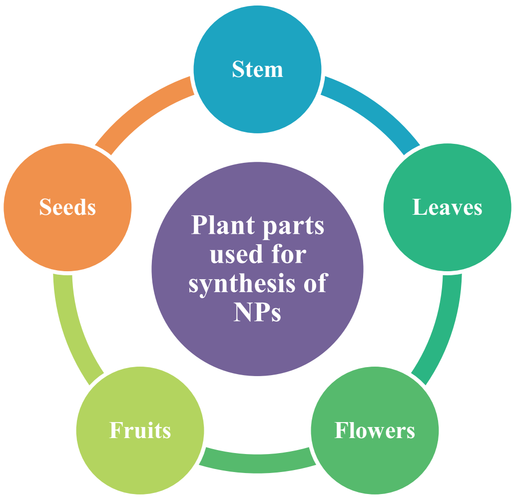
Table 2.1 Different types of plant-based metallic nanoparticles (Kuppusamy et al. 2016)

Plant used	Part of plants	Nanoparticles	Shape	Size (nm)	Plants involved in bioremediations
Acalypha indica	Leaf	Ag, Au	Spherical	20–30	Quercetin, plant pigment
Alternanthera sessilis	Whole	Ag	Spherical	40	Amine, carboxyl group
Aloe vera	Leaf	In_2O_3	Spherical	50	Biomolecules
A. paniculata	Leaves	Ag	Spherical	67–88	Alkaloid, flavonoids
A. mexicana	Leaves	Ag	Spherical	20–50	Proteins
Boswellia serrata	Gum	Ag	Spherical	70–90	Secondary metabolites
Caria papaya	Fruit	Ag	Spherical	15	Catechins
Cassia fistula	Stem	Au	Spherical	55–98	Hydroxyl group
Cinnamon zeylanicum	Leaves	Ag	Spherical	45	Water-soluble organics
Citrullus colocynthis	Calli	Ag	Triangle	5–70	Polyphenols
Citrus sinensis	Peel	Ag	Spherical	35	Water-soluble compound
Dillenia indica	Fruit	Ag	Spherical	11–24	Biomolecules
Dioscorea bulbifera	Tuber	Ag	Rod-triangular	8–24	Ascorbic acid
Euphorbia prostrata	Leaves	Ag	Rod, spherical	52	Proteins, phenols
Mirabilis jalapa	Leaves	Au	Spherical	90–150	Polysaccharides

2.6.2 Stem

Shameli et al. in 2012 investigated the stem of *Callicarpa maingayi* with removed methanolic group utilized for amalgamation of AgNPs and shaped [Ag (Callicarpamaingayi)] + complex. The plant extracts have aldehyde collections, and it's for the most part associated with the decrease of silver particles into metallic Ag nanoparticles. The distinctive useful gathering demonstrates amide and polypeptides that are dependable mixes with topping of ionic substances into metal NPs. The atomic examinations on biosynthesis of silver precious stones are intricate and not yet completely comprehended. Be that as it may, some past investigations are proposed demonstrating components of nanoparticle cooperation with pathogenic living beings. The biologically produced silver nanoparticles have protein external cell mass of microscopic organisms, growths, or entities of viruses that degrade the lipoproteins of microbe cell divider. At last the division of cell was ceased and cell prompts passing. At room temperature silver nanoparticle photosynthesis utilized extracts of *Cissus quadrangularis* (Vanaja et al. 2013). The removed stem of some portion of plants demonstrates the distinctive utilitarian gatherings, especially the amine, phenolic, carboxyl, and aggravates that are associated with the decrease of silver particles. Thus, incorporated silver nanoparticles indicate greater action against *Bacillus subtilis* and *Klebsiella planticola* pathogenic microscopic organisms. Along these lines, the biosynthesized metal nanoparticles went about as great antibacterial specialists. Various plant parts involved in formation of nanoparticles are shown in Fig. 2.4.

Fig. 2.4 Different types of parts of plants involved in synthesis of nanomaterials



2.6.3 Seeds

A few seeds that extricate like that of fenugreek contain high substance of secondary metabolites like flavonoids and other bioactive items, for example, lignin and nutrients. *Chloroauric corrosive* could be utilized for breakdown of solid parts of the fenugreek seeds. The COO gathering (carboxylic) and C=N and C=C useful gatherings are separately lying in the seed. The useful gathering of metabolites goes about as a surfactant of GNPs, and the flavonoids can settle the electrostatic adjustment of GNPs (Mittal et al. 2013). The fluid drawouts of *Macrotyloma uniflorum* impact the decrease of silver particles. Caffeic corrosive might be expected in the concentrate. Subsequently, decreased caffeic corrosive response could happen in one moment.

2.6.4 Fruits

Gopinath et al. (2012) utilized plant organic product of *Tribulus terrestris* extricate with expansion of various molar convergences of silver nitrate arrangement so as to incorporate eco-accommodating silver NPs with certain morphological highlights. The concentrate contains dynamic phytochemical that are subject for the single step decrease response. The round states of AgNPs were delivered by the *T. terrestris* extricates and proved commendable antimicrobial action against multidrug safe human pathogens. There is comparable cover utilizing polyphenol from grapes to combine palladium NPs and act viably against bacterial maladies (Amarnath et al. 2012). Not withstanding this, *Rumex hymenosepalus* serves as a balancing out operator for AgNPs. The utilization of ideal physic-concoction strategies to create nanomaterials is exceptionally valuable in pharmacological proposition to treat numerous endemic illnesses.

2.6.5 Leaves

Leaves that extricate are utilized as mediators to shape nanoparticles. Leaves of *Murraya koenigii*, *Centella asiatica*, and *Alternanthera sessilis*, including various leaves separate, are studied. Most recently leaves of *Piper nigrum* contained a critical bioactive material which is taking an interest in the nanoparticle arrangement by eco-philic strategy. The naturally orchestrated silver nanoparticles of 100 lg/ml concentration were dynamic medication, which focus on HEp-2 and HeLa cell line to control the ordinary biological work in disease cells. The AgNPs are powerful medication in malignant growth treatment to fix oncology in addition to terrifying disorders. *P. nigrum* removes longumine, it goes about as a topping operator for the arrangement of AgNPs and may upgrade the cytotoxic impacts of the tumor cells (Jacob et al. 2012). A green blend of AgNPs utilizing plant *Artemisia nilagirica* leave extracts has been depicted by Vijayakumar et al. (2013). It is by all accounts a crucial device for antimicrobial operators for now and close fates like that of silver nanoparticle amalgamation from the plants that control diverse pathogens in human.

2.7 Plant-Derived Formation of Silver Nanoparticles

Both physical and chemical methods had been used for the synthesis of silver nanoparticles for an extended period, but now for this purpose, developments have found the principal role of biological systems (Fig. 2.5).

Chemical and physical procedures are energy-exhaustive operations which indicate high production cost. Synthesis of AgNPs by chemical methods such as ethylene glycol, hydrazine hydrate, sodium borohydride, and dimethyleformamide can cause absorption of dangerous chemicals on the nanoparticle surfaces leading to toxicity problems (Iravani 2011). Furthermore, aqua chemical paths form nanocrystalline silver colloids which show accumulation with time, which means accommodation with the size factor upon storage. Plant derivatives have been explored as much better nominees over other biological systems, e.g., fungi and microorganisms, among the bio-based formation of silver nanoparticles, as they do not demand

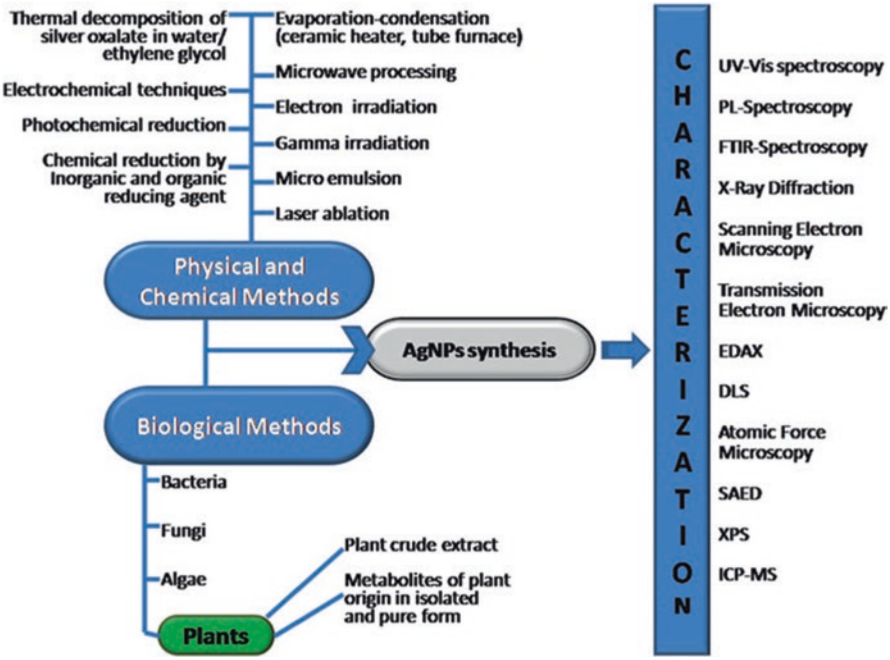


Fig. 2.5 Chemical, physical, and biological methods for the synthesis of AgNPs and the techniques employed for the characterization of produced nanoparticles (Patel et al. 2015a, b)

Table 2.2 Investigations by several researchers on plant-based AgNP synthesis and characteristics of formed nanoparticles

Plants	AgNP specifications	Plant parts	References
Citrus sinensis	10–35 nm	Peel	Kaviya et al. (2011)
Allium sativum	Spherical, 7.3 nm	Garlic cloves	Rastogi and Arunachalam (2011)
Allium cepa	Spherical, 33.6 nm	Leaves	Saxena et al. (2010)
Capsicum annuum	Spherical and crystalline, 10–70 nm	Fruit	Li et al. (2007)
Daucus carota	31–52 nm	Taproot spherical	Mukunthan and Balaji (2012)
Eucalyptus globulus	5–50 nm	Bark	Astalakshmi et al. (2013)
Mangifera indica	Triangular, hexagonal, and nearly spherical, 20 nm	Leaves	Philip (2010)
Ocimum sanctum	5–10 nm	Root and stem	Ahmad et al. (2010)
Piper betle	17–120 nm	Leaves	Rani and Rajasekharreddy (2011)
Zingiber officinale	6–20 nm	Rhizome	Kumar et al. (2012)
Trachyspermum ammi and *Papaver somniferum*	60–80 nm	Seeds	Vijayaraghavan et al. (2012)
Rosa rugose	12 nm	Leaves spherical	Dubey et al. (2010)
Svensoniahyderobadensis	24 nm	Roots	Rao and Savithramma (2013)
Parthenium hysterophorus	20–70 nm	Leaves	Anwar et al. (2015)

harmful capping and reducing factors, high temperature, radiation, fungal/microbial strains and expensive media for growth of microbes/fungi as well as for the production of nanoparticles. During formation and implementation zones, they also minimize the possibility of contamination or infection (Borase et al. 2014).

Many other researchers have also investigated the participation of several plant-based metabolites like amines (Prasad et al. 2011), flavonoids, polyphenols, terpenoids (Marimuthu et al. 2011), aldehydes, ketones (Chandran et al. 2006), starch (Vigneshwaran et al. 2006), arabinose and galactose (Kora et al. 2010), and saponins (Elavazhagan and Arunachalam 2011) in AgNP formation. Table 2.2 shows utilization of various plant parts in the formation of silver nanomaterials.

2.8 Plant-Based Gold Nanoparticle

Gold-derived nanoparticles have several applications in various fields. Au(3+) ion is reduced to the Au atom by binding of the atom to the cell surface, whereas further reduced Au also combines and clumps to produce GNPs. Au ions have good chances

Table 2.3 Plant-based synthesis of gold nanoparticles

Plants	AuNP size	Plant parts	References
Citrus maxima	25.7710 nm	Fruit	Yu et al. (2016)
Ixora coccinea	5–10 nm	Flower	Nagaraj et al. (2011)
Coleus forskohlii	5–18 nm	Root	Naraginti et al. (2016)
Cassia fistula	55.2–98.4 nm	Stem bark	Daisy and Saipriya (2012)
Punica granatum	70 nm	Fruit peel	Ganeshkumar et al. (2013)
Argemone mexicana	22–26 nm	Leaf	Varun et al. (2015)
Hygrophila spinosa	50–80 nm	Leaf	Koperuncholan (2015)
Abelmoschus esculentus	45–75 nm	Seed	Jayaseelan et al. (2013)
Morinda citrifolia	12.17–38.26 nm	Root	Suman et al. (2014)
Hibiscus sabdariffa	10–60 nm	Leaf and stem	Mishra et al. (2014)

at the starting phases to attach with the atom and produce clumps (Cai et al. 2011). GNPs have applications in the field of medicine (Honary et al. 2012). The bio-based synthesis of nanoparticles has specific morphology and determined shapes such as hierarchical tubes, triangle, hexagonrods, decahedrons, icosahedrons, and nanotriangles as well as nodous ribbons. Different nanoparticles have different efficient applications in various fields; thus researchers are now focusing on their shapes (Du et al. 2007). GNPs are being produced by utilizing several plant parts, e.g., stem, leaf, root, and fruit as showed in Table 2.3.

2.9 Plant-Based Zinc Oxide Nanoparticles

Zinc oxide (ZnO) nanoparticles are currently of greater interest due to their certain characteristics, e.g., their production is cheap, safe to use, and can be synthesized easily (Elumalai et al. 2015). The reason of the attention of researchers toward zinc oxide NPs is their vast applications in the sector of optics, electronics, and biomedical systems (Azizi et al. 2014). ZnO nanoparticles show enormous applications as anti-inflammatory (Ramesh et al. 2015) and wound-healing characteristics (Nagajyothi et al. 2013). They have ultraviolet filtering characteristics thus being used in cosmetics, e.g., sunscreen creams and lotions. They have also vast applications in medicines such as anticancer, drug delivery, antifungal, antibacterial, antidiabetic, and agricultural characteristics (Ramesh et al. 2015). They have also been used in manufacturing rubber and paint, in applications in dentistry, and in eliminating arsenic and sulfur from water (Ali et al. 2016). Anbuvannan et al. (2015) reported ZnO nanoparticles have several morphologies like nanorods, nanowires, nanoflowers, nanoflakes, and nanobelts. Table 2.4 shows plant-based synthesis of ZnO NPs derived from different plant parts like flowers, stem, leaves, and fruit peels.

Table 2.4 Plant-based synthesis of ZnO nanoparticles

Plants	Shape	Plant parts	References
Rosa canina	Spherical	Fruit extract	Jafarirad et al. (2016)
Solanum nigrum	Hexagonal and quasispherical	Leaf extract	Ramesh et al. (2015)
Cocos nucifera	Spherical and hexagonal	Coconut water	Krupa and Vimala (2016)
Gossypium	Spherical and nanorod	Cellulosic fiber	Aladpoosh and Montazer (2015)
Calotropis gigantea	Spherical	Fresh leaves	Vidya et al. (2013)
Nephelium lappaceum	Spherical and hexagonal	Fruit peels	Yuvakkumar et al. (2015)
Coptidis rhizoma	Spherical and rod shaped	Dried rhizome	Nagajyothi et al. (2014)
Vitex negundo	Hexagonal	Flowers	Ambika and Sundrarajan (2015)

2.10 Biofuel Applications of Nanoparticles

Commercialization process of biofuels is limited due to hinders in their production processes. Productions of high-energy yield and cost-effective biofuels are the main challenges. Nanoparticles in this regard may play a significant role in forming this process economically viable.

2.10.1 Role in Pretreatment

Most frequently found biopolymer is the lignocellulosic biomass rich in carbohydrate content. Two-thirds of the lignocellulosic biomass consists of cellulose and hemicellulose and are among the cheapest sources for production of biofuel (Srivastava et al. 2015a). Lignin barrier is removed prior to saccharification by pretreatments to expose cellulose and hemicellulose (Alvira et al. 2010). Biological and chemical pretreatment methods are common among various pretreatment procedures for breakdown of lignocellulosic matter (Srivastava et al. 2015a). Although pretreatment is considered as the expensive phase in the transformation of cellulose, it has the ability to enhance the efficiency remarkably and lower the net cost of biofuel production (Alvira et al. 2010; Srivastava et al. 2015a). Degrading enzymes, e.g., cellulases and hemicellulases, are employed after the pretreatment to liberate the fermentable sugars (Rawat et al. 2014). Thus many investigators are working on pretreatment process to improve the bioconversion efficiency of lignocellulosic biomass. Wei et al. (2015) observed that production of sugar from corn stover was improved in the existence of iron oxide nanoparticle by employing the acid pretreatment. Furthermore, nanoparticle-acid pretreated substrate exhibited nearly 13–19% more xylose and glucose relative to control (acid-treated substrate without nanoparticles). This study found that iron oxide nanoparticle can aid the pretreatment process, as results exhibited improved sugar formation over the metallic iron nanoparticles. The experiment was conducted at 100 °C which showed its economic viability, and the reported data exhibited a positive link among the concentrations of released sugar and iron during the biomass pretreatment. In another investigation done by Yang et al. (2015), breakdown of cellulosic biomass was improved in the existence of decreased graphene oxide functionalized with iron oxide nanoparticles. The iron oxide reduced graphene oxide-SO_3H (Fe_3O_4-RGO-SO_3H); nanocomposite was successfully produced employing the reduced graphene oxide (RGO), containing iron oxide nanoparticles and benzene sulfonic acid which were directly harbored on the surface of RGO through C-C covalent bonds. The distinctive structure of Fe_3O_4-RGO-SO_3H nanocomplex along with increased dispersion in water sustains the reachability of cellulose to the active sites and enhances the production of sugar which can further be employed for the biofuel production. Although these investigations have explored a new zone for the production of biofuels employing the nanoparticles, currently this avenue is at the very initial phase. So, many more attempts to improve the economic sensibility are needed.

2.10.2 Role in Cellulase Production and Stability

After the pretreatment process, enzymatic hydrolysis is done by cellulases to degrade lignocellulosic biomasses. For enhanced enzymatic hydrolysis, greatly efficient cellulases are needed, which are capable of working in unrelenting conditions. Furthermore uses of several cofactors, e.g., metal ions, are reported in the many investigations other than various substitute methods to make enhanced cellulase efficiency and its production in industries (Srivastava et al. 2014). To increase the stability of enzyme application of nanoparticles is a new avenue in the area of bioenergy production (Srivastava et al. 2014; Singh et al. 2016a, b). Few but encouraging and potential investigations have been outlined in this field currently. The study by Dutta et al. (2014) noticed an enhanced production of cellulase in the existence of hydroxyapatite nanoparticle employing the bacterial strain. Highly thermostable enzyme was used in this research which kept its half-life at 80 °C. Besides enhanced thermal stability, these authors also observed an enhancement in reducing sugars when substrates, e.g., rice husk and rice straw, were used. Similarly Srivastava et al. (2015a) reported an improved cellulase production, its thermal strength, and sugar production in the existence of iron oxide/alginate nanocomplex. A higher sugar yield was observed in this study by employing thermotolerant fungal sp. *Aspergillus fumigatus* AA001 in the solid-state fermentation using the same nanocomplex. Furthermore, thermal stability of cellulase enzyme was also improved besides its production in the existence of uncovered iron oxide nanoparticle as relative to control. The production of cellulase was enhanced in the existence of pure iron oxide nanoparticle and iron oxide/alginate nanocomposite by 35% and 40%, respectively, when compared to control. In addition, iron oxide/alginate nanocomplex treated cellulase exhibited its thermal stability at 70 °C for 8 h by maintaining its 56% of relative activity, whereas crude cellulase could keep only 19%. These investigations distinctly evince that the nanoparticles may play a significant part to change the whole process of bioconversion. Srivastava et al. (2014) suggested that the major cause of enhancement in the thermal stability of cellulase was cellulase immobilization on to the nanoparticles. Besides, thermal stability and an improved cellulase production have been noticed in the existence of nickel cobaltite nanoparticle by thermotolerant *Aspergillus fumigatus* NS (class: Eurotiomycetes) through solid-state fermentation. Furthermore, untreated cellulase showed thermal stability at 80 °C for 7 h in the presence of $NiCo_2O_4$ nanoparticles, whereas at the same temperature, untreated cellulase was stable up to 4 h. Moreover it was also observed that production time was lessening in the existences of nanoparticles in above studies. Therefore, in the near future, nanoparticles may prove their capability in biofuel production process. Verma et al. (2013) reported improvement in the above stated investigations; there are also many researches that have concluded improvements in the hydrolysis efficiency of cellulases besides its better production and thermostability in the presence of various kinds of nanomaterials, e.g., iron oxide, zinc oxide nanoparticles, etc. Ansari and Husain (2012) immobilize cellulase on iron oxide magnetic nanoparticles. They reported that the nanoparticles may act as a carrier and provide resistance against the unfavorable pH and inhibitor besides thermal stability. Verma et al. (2013) observed that the thermostability of the enzyme β-glucosidase was enhanced in the occurrence of iron oxide magnetic nanoparticles and showed the half-life of that enzyme at 70 °C. As nanoparticles have explored a new path to enhance the production of cellulase and its thermal stability, their exact mechanism is not well known. So, further studies are focusing on this specific area for its industrial and economic viability.

2.10.3 Role in Saccharification

Saccharification or hydrolysis of lignocellulosic biomass is the next phase after pretreatment to liberate sugars using cellulase enzyme. Temperature 45–50 °C needed for enzymatic hydrolysis makes the whole process slow, more vulnerable to contamination by microbes, and usually incomplete, ending in decreased production of fermentable sugars and demand greater enzyme quantity. Hence, it is suggested that these bottlenecks can be overcome by employing the thermostable cellulase enzymes and thermophilic microbes (Yeoman et al. 2010). Cellulase that can tolerate increased temperatures can also work at higher hydrolysis temperatures. The presence of nanoparticles enhances the thermal stability of cellulase, and these thermostable cellulases may perform significantly at higher degradation temperatures. Some current investigations concluded the enhanced thermostability and degrading efficacy at increased temperatures (Dutta et al. 2014; Srivastava et al. 2015a, b).

Dutta et al. (2014) employed rice husk/rice straw as substrates, and improved thermal stability of cellulase enzyme was observed resulting in enhanced production of sugar in saccharification process. In this study calcium hydroxyapatite nanoparticles were used, and substrates were treated at 80 °C to get reducing sugars. Srivastava et al. (2015b) used iron oxide/alginate nanocomposite and found betterment in degradation efficacy of cellulase enzyme and sugar yield at 70 °C. Under the solid-state fermentation, greater sugar yield was reported at higher temperature employing *Aspergillus fumigatus* AA001 in the occurrence of iron oxide/alginate nanocomplex. Though nanoparticles have greater capability to enhance the degrading efficacy of cellulase enzyme, their mechanism is not very clear; so attention must be paid in this aspect for industrial scale production.

2.11 Optional Metabolite Impact on Bio-decrease Response

A considerable portion of the optional metabolites and a few proteins have reasonably advanced the combination of NPs which are metallic in nature from the other ionic mixes. The decreased response principally included plant biomolecules (optional metabolites, e.g., sugars (polysaccharides), proteins, natural mixes, shades, and plant tars. Plant normal items are engaged with the decrease response to incorporate green nanoparticles. Plants are especially taking an interest in guard components to create different substance mixes, for example, polyphenols, saponins, and cell reinforcement chemicals, like alkaloids. The proposed decrease response illustrated the primary components for the biological synthesis of metallic NPs. The plant removes various useful collections, for example, alkenyl, phenolic and liquor, amine, and carboxylic group. It is for the most part indicated as plant auxiliary metabolites and may be miniaturized scale and large-scale biomolecules (Jha et al. 2009). These substances are completely taking an interest for the NP generation. For example, *R. hymenosepalus* plant removes the advances of NP unions with quick response energy. Consequently, the dissolvable concentrate of *R. hymenosepalus* is rich in polyphenols, for example, stilbenes and catechins, atoms that go about as diminishing and balancing out specialists for silver NPs creation (Awwad et al. 2013).

2.12 Business Uses of Biosynthesized Nanoparticles

2.12.1 NPs in Waste Treatment NPs

Nanoproducts have various applications in everyday life. There are different ecologically accommodating products accessible in business showcase which are highly efficient, for example, bone and teeth concrete and handcrafted items (Kouvaris et al. 2012). For example, Au, Ag, and platinum NPs have wide applications in beauty products and they are utilized as fixings in different items, like, to protect against the UV rays sun blockers, toothpastes, mouthwash, and fragrances and shampoos (Kumar and Yadav 2009). NPs of silica act in fixing business items. The altered silica NPs are utilized as pesticide, and it is utilized in an assortment of non-farming implementations.

2.12.2 Beautifiers

Metallic NPs are utilized as additive specialists in restorative enterprises. New element of metallic nanoparticles is utilized for various business applications, for the most part beauty care products, medical materials, and sustenance additives (Songand and Kim 2009; Kokura et al. 2010). The metallic NPs like the platinum, gold, and Ag are connected for some business items, for example, soap, detergent, shampoo, and shoes.

2.12.3 NPs in Food Industry

Some metals like silver are quick warmth directing; therefore, nano-Ag is utilized in different mechanical frameworks. It is predominantly utilized in warmth-inclined instrumentation like in PCR cover (Weiss et al. 2006). In food businesses, sustenance items have very high microbial sullying because of different procedures, for example, assembling and handling of crude materials. Consequently, requirement is there to build up a savvy biological sensor to decide the nature of the items.

2.13 Component Blend of Metallic NPs

Difference highlighted in hydrogen particles is basically a reaction by variation in size and states of NP arrangement. Shankar et al. (2003) revealed that the extracts of *Aloe vera* provided Au-Ag center NPs in different sizes by changing the pH of the medium which is dissolvable. So, biologically synthesis of NPs by hay plant concentrate have variable size.

2.14 Conclusion

Environmental hazards caused by chemical synthesis of nanoparticles have urged synthesis of nanoparticles using plant means, as it includes eco-friendly methods for the synthesizing nanoparticles. This chapter focused on the plant-based nanoparticles and methods of their synthesis. Various plant parts, e.g., leaves, flowers, roots, stems, fruit and its peels, etc., are being used for the green synthesis of nanoparticles especially metallic nanoparticles. This chapter also overviews the applications of these plant-based nanoparticles in different fields, e.g., medical, agriculture, food industry, and cosmetic industry.

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